

Working Group 3

Mars "Surface" Exploration

Co-Chairs:

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Working Group 3 Statistics

- Aerial Exploration (7 abstracts)
 - Landing Concepts (3 abstracts)
 - Surface Exploration Technologies
 - Rovers and Instruments (10 abstracts)
 - Subsurface Exploration (7 abstracts)
 - Science Applications (9 abstracts)
- ↳ 36 abstracts; 5 cancellations/no-shows

Working Group 3 in a Larger Context

Desired products:

- Concepts
- Strategies
- Trends and Themes
- Technologies (new or evolving)

WG-3 Response

- No
- Yes
- Yes
- Many

Key Investigations, following MEPAG:

- **H₂O Inventory:**
 - Atmosphere
 - Surface
 - Sub-surface

Yes
Yes
Yes

- **Other Resources:**
 - Geological
 - HEDS

Yes
Yes

- **Life:**
 - Past
 - Present

Yes
Yes

- **Climate:**
 - Now
 - Ancient
 - Change

Yes
Yes
Yes

WG 3 Subject Categories

- Entry, Descent, and Landing
- Lander Payload Elements
- Aerial Exploration
- Rovers and Attached Payloads
- Subsurface Exploration

Category: Entry, Descent, and Landing

- Required for all surface or aerial missions
 - Accurate landing
 - Hazard avoidance
 - Hazard tolerance
- Elements of Smart/Robust EDL
 - Approach guidance and navigation
 - Guided entry systems
 - Maneuverable parachutes
 - Descent navigation
 - Precision terminal guidance
 - Hazard avoidance
 - Lightweight hazard tolerance

Issues: Entry, Descent, and Landing

- 3-6 km landing accuracy with hazard avoidance by 2005 without local infrastructure
 - Pinpoint delivery (10's of meters) by 2007-'09
 - 30° slopes with 1 m terrain features by 2005
 - Evolutionary reduction in EDL system mass fraction requires continuing investment, e.g.:
 - Montgolfier balloons
 - Small air bags
- ➔ Technology development must start now to enable these capabilities for '05-'07-'09 missions

Category: Aerial Exploration (Aircraft)

<i><u>Approach</u></i>	<i><u>Relevance to Themes Which are Enabled?</u></i>	<i><u>Mars Readiness Level</u></i>	<i><u>Comments/Issues</u></i>
Small aircraft, small payload: <ul style="list-style-type: none"> - multiple systems - 100 km, 80-150 m/sec, 20-60 min - > 25 kg entry mass - targeted navigation 	Climate, meteorology, geology	Moderately high: Low altitude tests High alt tests underway Wind tunnel simulations	Communications require synchronization with orbiter.
Small aircraft (transonic/supersonic): <ul style="list-style-type: none"> - higher ranges (100-1000's of km) - 20-60 min duration - 100 kg entry mass - targeted navigation 	Climate, meteorology, regional geology	Same as above	Communications required to survive landing Spectral Imagery compromised due to vel.
Airplane navigation: <ul style="list-style-type: none"> - Inertial nav - image based nav, 2-3 m accuracy - focussed data acquisition - precision probe delivery - return to site 		Being worked. Inertial nav is developed Analytical simulations done using MOC data Military precedent	Communications with orbiter Throughput limits.
Vertical Lift Rotocraft <ul style="list-style-type: none"> - range 100-300 km - m~10-50 kg, v~20-50 m/sec - surface launch & relaunch - 2-3 hr duration - Fuel-cell or liquid fuel 	Climate, meteorology, geology	Readiness level low: High altitude paper studies only No ground tests yet	Analyses based on extrapolation to low pressure Vehicle autonomy issues

Category: Aerial Exploration (Aerobots)

<i><u>Approach</u></i>	<i><u>Relevance to Themes Which are Enabled?</u></i>	<i><u>Mars Readiness Level</u></i>	<i><u>Comments/Issues</u></i>
Balloons- Montgolfieres: <ul style="list-style-type: none"> - gentle payload landings - ~10 hr flights possible - > 4 kg with 1 kg payload (or larger) - Multiple landings - Low risk (leaks) - ~10 kg entry mass 	Climate Meteorology, Resources Surface	Low altitude tests done High alt in progress 3 successful thus far	Must confirm high alt deployment reliability
Balloons- Positive pressure: <ul style="list-style-type: none"> - 7-100 days duration - ~ 10⁴ km - 2-20 kg payload - 40-200 kg entry mass - 2-6 km altitude 	Same	Low altitude tests done High alt tests underway	Materials
Multi-touch surface sampling <ul style="list-style-type: none"> - use altitude controlled Montgolfiere to sample multiple places 	Same	Altitude control demonstrated Simple drill demonstrated	Getting stuck on rocks.

Issues: Aerial Exploration

- Propulsion and power systems
 - Lightweight materials
 - High altitude validation
 - System autonomy/navigation and guidance
 - Communications
- ➔ Unique potential for quickly examining large regions of the surface and atmosphere

Category: Lander Payload Elements

<i><u>Approach</u></i>	<i><u>Relevance to Themes Which are Enabled?</u></i>	<i><u>Mars Readiness Level</u></i>	<i><u>Comments/Issues</u></i>
TEGA Evolved Gas Analyzer	Directly addresses volatiles on surface	High- flight ready	Needs sample acquisition system (e.g. robotic arm)
Robotic arms	Enabling technology for future and in-situ instruments	Orbital heritage	Risk mitigation Limited operating range
Getting off the lander (Frisbee)	Enabling technology for small S/C in-situ instruments	Rosetta heritage- simple	Needs prototyping
E-field sensing (ARES)	Characterize charge state and build-up in atmosphere. Enabling technology	Heritage from balloon experiment; Under prototype; Low mass	Low power, Low data rate
IPSE, Italian Sci. Exper Pkg. (IR Spectrometer/ microscope,Rad detector, Geochemistry, Atmos- pheric dust experiment, 1 meter drill, x-ray fluorescence)	ISA & NASA selected payload for '03	High	Drill- DEEDRI provides samples to IR spec, x-ray
X-ray fluorescence (IPSE)	Elemental abundances (Geology/geochemistry) High	High: Heritage from INTEGRAL; Space qualified	Working Group 3 Mars Surface Exploration

Issues: Lander Payload Elements

- Science instruments
 - Bring sample to instrument (e.g., TEGA)
 - In-situ/close (e.g., APXS)
 - In-situ/far (e.g., LIBS)
- Getting instruments to samples/samples to instruments
 - Drills
 - Manipulators (limited range from deck)
 - Rovers (lander/rover trades)
 - Deployment/drive-off systems (e.g., "frisbee")
 - Multiple landers (e.g., scouts)

Category: Rovers and Attached Payloads

<i>Approach</i>	<i>Relevance to Themes Which are Enabled?</i>	<i>Mars Readiness Level</i>	<i>Comments/Issues</i>
FIDO Rover Program -Rover test-bed with payload	Surface/ subsurface Geology Ancient climate	N/A	Essential test-bed Enables critical flight- like field trials
Beagle-2, Mars Express (Rover "of sorts")	Mission concept	in '03	Cannot address
Scouts- What are they?	Strategy; Depends on payload and implementation plan	could be for '05	Scope and imple- mentation
Mature Nanorovers (MUSES-CN)	Geology rovers with small payloads	Being built for launch in '02	Flight spares. Spectrometer wrong for Mars Navigability?
ESA micro-rovers	Same as above	Exists in lab	Tread geometry Navigability?
Inflatable rover	Geology rover	Field testing	Good tractability. Range? Packaging? Leakage?
Cooperative robotics	Water, life searching rover swarms	Concept	Good redundancy May lack flexibility
Raman Spectrometers	Surface, water, past life, geology	Athena-EM design IR-prototype Could begin fab if funded	Wavelength (VIS more mature & stronger sigs)
Stand-off elemental analysis (LIBS)	Geology, HEDS, climate history	Field prototype	Good survey tool

Removal of King Group 3
Quantitative
Mars Surface Exploration

Issues: Rovers and Attached Payloads

- Need a set of mission-based requirements
- Broad base of concepts and innovative approaches
- No presentations on larger range of rovers
- Long duration rovers
- Instruments missing, e.g.:
 - Neutron spectrometers
 - Microscopy

Category: Subsurface Exploration

<i><u>Approach</u></i>	<i><u>Relevance to Themes Which are Enabled?</u></i>	<i><u>Mars Readiness Level</u></i>	<i><u>Comments/Issues</u></i>
Cone Penetrometers	Climate (current & recent) Life (redox potential)	1-2 years to develop	Rod handling
Near Surface Sampling (to ~10 m)	Same	2-3 years to develop	Dry drilling Sample handling
“Shallow” drilling (~ 200 m)	Many: Climate, resource issues, water, life(?)	3-5 years to develop	Drilling autonomy Bit design
Deep drilling (>500m)	All of the above, plus HEDS resources, ancient climate, extinct life, present life?	5-20 years Very ambitious	Steering Bit life Well control & stability Cross contamination Planetary protection Down-hole thrusting Probably requires manned presence

Issues: Subsurface Exploration

- Autonomous drilling (little Earth experience)
- Drill bit design (no replacement) - dry drilling
- Science sample recovery
- Planetary protection
- Deep drilling (~500m) very ambitious w/ tremendous payoff
- Geophysical data could lower risks

Summary

- There's a wealth of ways to do Mars exploration - there's no single right way
- Within 5-year period, NASA can address most of the issues in our theme area given a strong technology program
- Need flight opportunities which accommodate advanced technology